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SERENDIBITE FROM WARREN COUNTY, NEW YORK, AND ITS PARAGENESIS

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ABSTRACT

Serendibite has been found in considerable abundance a few miles west of Johnsburg in Warren County, New York, the second known occurrence of this boro-silicate. It occurs in Grenville limestone near its contact with an intrusive granite and is of hydrothermal-contact-metamorphic origin. It is associated most closely with abundant colorless diopside and pale phlogopite. Other associated minerals are spinel, scapolite, orthoclase, plagioclase, calcite, tremolite, sericite, and two undetermined minerals.

The serendibite is massive, showing no crystal faces, and is optically triclinic with an axial angle near 90° and is in part optically + and in part optically −. Its indices of refraction and pleochroism are:

$\alpha = 1.701$, very pale yellowish green.
$\beta = 1.703$, nearly colorless.
$\gamma = 1.706$, Prussian blue.

It has prominent polysynthetic twinning resembling that of the plagioclase feldspars. The optical orientation is shown in Figure 2.

Two analyses of the serendibite from New York are given yielding the formula $3Al_2O_3 \cdot 4MgO \cdot 2CaO \cdot B_2O_3 \cdot 4SiO_2$.

OCCURRENCE AND ASSOCIATION

Serendibite, a boro-silicate of alumina, lime, and magnesia, has been previously reported only from the type locality in Ceylon. It occurs in considerable abundance in New York State where it was found by Mr. John Puring of New York City, on the farm of Mr. J. Noble Armstrong, about half way between Johnsburg and Garnet Lake, in Warren County, New York. The occurrence was later examined and studied by Larsen, the chemical analyses were made by Schaller, and the present paper is a report of these investigations.

The grayish blue-green serendibite (analysis given in Table 1) occurs just above the alluvium about half a mile northwest of Mr. Armstrong's house in a small gulch in the Grenville limestone near its contact with gneissoid granite. The Grenville beds dip about

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[1] Published with the permission of the Director, United States Geological Survey.

45° south in the same direction as the slope of the hill but more steeply, and the section of the beds here, from the top down, is:

Limestone—about 100 feet.

Mica gneiss—about 40 feet.

Limestone, with many silicates including serendibite, and aggregates of quartz—about 60 feet

Mica gneiss.

The mica gneiss is well banded and is made up chiefly of andesine, with some microcline, dark biotite, diopside, magnetite, and apatite. It was probably derived from a marl.

The limestone on the lower slopes of the hill, at the serendibite outcrop, is a rather coarse-grained marble which carries several per cent of diopside grains more or less altered to pale green serpentine, and locally a little nearly colorless phlogopite, and rarely scapolite or graphite. In many places the marble contains nodules up to several feet across which are made up chiefly of white diopside, some calcite, rarely phlogopite, tremolite, graphite, albite, and secondary serpentine and talc. Some of these nodules are bordered by pale phlogopite which seems to be later than the diopside. Many of the nodules are altered to serpentine along their borders with a fairly sharp contact between the unaltered and the serpentinized parts. The limestone is cut by several vein-like bodies, up to several feet across, of nearly pure white diopside rock with borders rich in phlogopite.

Near the top of a low hill, just east of the main serendibite occurrence, there are some small bodies of a white granular rock made up chiefly of feldspar, mostly albite in one specimen and microcline-perthite in another, and showing smaller quantities of grass-green diopside and colorless phlogopite. Much of the rock lacks quartz but one specimen collected contains large quantities. Diopside makes up from 5 to 10 per cent of the rock and phlogopite from 1 to 5 per cent. Brown titanite is abundant in two specimens and rutile in another. Calcite is present in small quantity and scapolite is present in one specimen. The rock is banded and the grains are interlocked or intimately intergrown. This rock is believed to be a metamorphosed limestone though it has some resemblance to granite.

Two other types of metamorphosed limestone were noted just above the serendibite and near a small body of granite. They contain much iron and in that respect differ appreciably from the other lime silicate rocks. One of these types consists of about equal quantities of red garnet and green diopside, with a little andesine, brown hornblende, sericite, apatite, and magnetite. It is similar to the garnet rock mined in this part of the Adirondacks. The other type consists chiefly of brown hornblende, with considerable andesine and a very little diopside.

The serendibite is associated with the diopside-phlogopite bodies. The best exposure, about six feet long, is just east of the small gulch and near the covered granite-marble contact. The mineral relations are shown diagrammatically in Figure 1. The lowest outcrop is a white diopside rock about a foot thick, over which is a thin discontinuous layer of phlogopite, above this are a few inches of rock containing serendibite, then another narrow layer of phlogopite, followed by six inches of rock with diopside and phlogopite, another narrow layer of phlogopite, six inches of serendibite rock, a foot with no exposures, and then marble with serpentinized diopside.

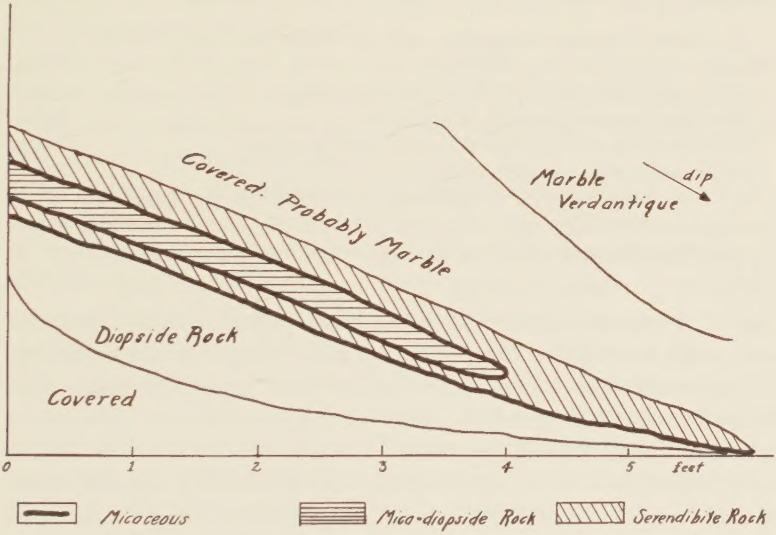

FIG. 1. Sketch of serendibite-bearing contact zone.

The serendibite layer is itself zoned microscopically, the zones from one to a few millimeters wide grading into each other. A characteristic section across 15 millimeters of this zone is:

(a) Serendibite with diopside and phlogopite.
(b) Diopside with phlogopite.

(c) Diopside and scapolite, intimately intergrown.
(d) Scapolite and phlogopite.
(e) Scapolite and andesine.
(f) Andesine.

The scapolite ($Ma_{40}Me_{60}$) borders and replaces the serendibite and is clearly younger. It is probably also younger than the diopside and feldspar. A little pale green tourmaline is locally associated with the serendibite.

Another specimen shows the following zoning for about 50 millimeters:

(a) Chiefly diopside, phlogopite, and serendibite with some altered scapolite	15 mm.
(b) Scapolite and diopside with a little phlogopite	4 mm.
(c) Orthoclase and scapolite, intergrown	3 mm
(d) Orthoclase with a little calcite and some scapolite	8 mm.
(e) Scapolite with some diopside	2 mm.
(f) Pure diopside, rather sharply separated from (e), but fingering into (g)	$\frac{1}{2}$ mm.
(g) Phlogopite in blades across the layer with a very little spinel and calcite	20 mm.

Smaller streaks of serendibite rock are present in the limestone about 150 feet up the hill east of the main body. Here the serendibite is confined to a band a few millimeters across. It forms large irregular anhedral crystals, many of which surround pale green spinel and is associated with much phlogopite, some diopside, tremolite, andesine, and calcite. Beyond the serendibite-bearing band is a layer a few millimeters across made up chiefly of andesine and phlogopite with a little diopside. Scapolite is present in the outer part of this layer and increases in quantity for another millimeter. Then comes a narrow zone of scapolite and diopside and finally fifteen centimeters of nearly pure diopside. In some specimens there is an outer narrow zone made up of colorless phlogopite and diopside. The phlogopite includes the diopside poikolitically.

The minerals closely associated with the serendibite are, in their approximate order of abundance: colorless diopside, nearly colorless phlogopite, plagioclase (andesine and labradorite), scapolite (wernerite), orthoclase, tremolite, pale green spinel with $n=1.720$ (analysis given in Table 3), magnesia tourmaline (dravite), chlorite, serpentine, sericite, talc, and several undetermined minerals.

Two of these (A and B) were studied optically and one (B) was partially analyzed.

The undetermined mineral (A) is optically negative, 2V small, $\rho<v$ strong, $\alpha=1.575$, $\beta=1.613$, $\gamma=1.614$. Density about 2.78. Its composition is unknown.

The second undetermined mineral (B) is closely associated with serendibite in the specimen that yielded the serendibite for analysis but was not found in other specimens. It is colorless. nonmagnetic even to a strong electromagnet, has a density greater than 3.20, is optically negative, with 2V rather large, slight dispersion, $\alpha=1.665$, $\beta=1.692$, $\gamma=1.705$. Partial analyses of this mineral are shown in Columns 2 and 3, Table 3, but material for a complete analysis was not available.

The serendibite and associated minerals are of hydrothermal contact metamorphic origin. The solutions brought in chiefly magnesia, silica, alumina, soda and potash, with some boron and chlorine. They were notably poor in iron.

The order of deposition of the minerals associated with the serendibite was only partly determined. The phlogopite appears to be in part later than the diopside. The serendibite appears to be later than the spinel and older than the diopside. It is partly replaced by the scapolite. The scapolite is probably younger than the albite and diopside. The tremolite is later than the diopside. The serendibite is in part replaced by sericite and the scapolite is more or less replaced by a cloudy, clay-like mineral and some sericite. The serpentine is late. The temperature of the main metamorphism must have been high as indicated by the presence of abundant diopside, spinel, and lime-soda feldspar.

The serendibite of the moonstone pits of Gangapitija, Ceylon, has a similar association and occurrence, and probably a similar origin.[2] Impure limestone beds are separated from granulite by successive layers of diopside alone, next the marble, and of diopside, serendibite, and spinel with some scapolite and plagioclase. The diopside next to the granulite layer is from 2 1/2 to 3 cm. across; the serendibite layer is from 1/4 to 2 1/2 cm. across.

OPTICAL PROPERTIES OF SERENDIBITE

The serendibite from New York is in part optically + with 2V near 90° (measured 83°). In part the mineral is also optically −. The indices of refraction and pleochroism are:

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[2] Coomáraswámy, A. K., The crystalline limestones of Ceylon: *Quart. Jour. Geol. Soc., London*, vol. **58**, pp. 420–22, 1902.

$\alpha = 1.701$, very pale yellowish green.
$\beta = 1.703$, nearly colorless.
$\gamma = 1.706$, Prussian blue.

It shows prominent polysynthetic twinning, resembling that of plagioclase feldspars. The optical orientation with respect to the twinning is shown in Figure 2 which was kindly furnished by Dr. Tom. Barth. The optical orientation of the two individuals is symmetrical with respect to the composition plane of the twins and hence the twinning axis is normal to the composition plane. The mineral is triclinic, judging from the optical relations. No crystal faces were observed, all of the material being massive.

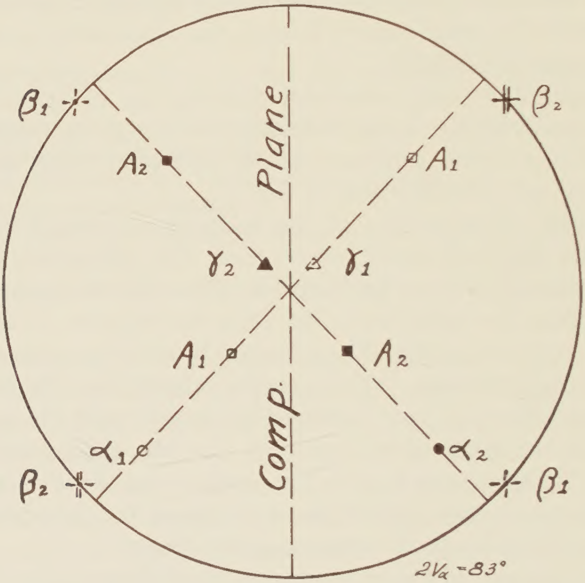

FIG. 2. Stereographic projection of the optical orientation of serendibite.

ANALYSIS AND COMPOSITION OF SERENDIBITE AND SOME OF ITS ASSOCIATED MINERALS

The analyses were made on two separate lots, carefully selected and purified, with the following results:

TABLE 1. ANALYSES OF SERENDIBITE

	New York				Ceylon
	1	2	Average	Ratios	Prior's analysis
SiO_2	26.37	26.23	26.30	3.95 or 4×0.99	25.33
Al_2O_3	33.96	34.13	34.05	3.01 or 3×1.00	34.96
FeO	2.76	[a]	2.76	3.81 or 4×0.95	4.17
MgO	15.44	[a]	15.44		14.91
CaO	13.17	13.43	13.30	2.14 or 2×1.07	14.56
B_2O_3	8.12	8.61	8.37	1.09 or 1×1.09	[4.17]
Etc.	.....	.....	.....		1.90[b]
			100.22		100.00

[a] Not determined.

[b] Na_2O, 0.51; K_2O, 0.22; P_2O_5, 0.48; Loss on ignition, 0.69.

Alkalies and water are practically absent; fluorine was not detected in a qualitative test. The analysis of serendibite from New York agrees well with that from Ceylon except for a higher B_2O_3 content, which was not determined directly on the Ceylonese material,[3] the value given being obtained by difference. The formula derived from the calculated ratios of the mineral from New York is $3Al_2O_3 \cdot 4MgO \cdot 2CaO \cdot B_2O_3 \cdot 4SiO_2$.

Ratios calculated from the analysis of the serendibite from Ceylon agree fairly well with those determined from the analysis of the New York serendibite, except for the B_2O_3, as is shown below in Table 2. Enough CaO is alloted to the P_2O_5 in Prior's analysis to form apatite and the alkalies are combined with the lime.

TABLE 2. RATIOS OF PRIOR'S ANALYSIS OF SERENDIBITE FROM CEYLON

SiO_2	0.4215=3.77 or 4×0.94
Al_2O_3	0.3427=3.07 or 3×1.02
(Mg, Fe)O	0.4281=3.83 or 4×0.96
CaO	0.2595=2.32 or 2×1.16
B_2O_3	0.0599=0.54 or $\frac{1}{2}\times1.00$

If the 34.96 percent of Al_2O_3 in Prior's analysis be assumed to include 2.77 per cent of retained B_2O_3, reducing the percentage of Al_2O_3 to 32.19, then the ratios of $SiO_2:Al_2O_3:CaO:(Mg, Fe)O$ become 3.97:2.98:2.46:4.05, agreeing very closely except for the CaO to the ratios 4:3:2:4, deduced from the analysis of the serendibite from New York. The ratio of B_2O_3 then is correspondingly raised somewhat. Even if the reported figure for Al_2O_3 is correct and contains no B_2O_3, the ratios of Prior's analysis are close to the simpler formula derived from the analysis of the New York serendibite, except for the B_2O_3.

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[3] Prior, G. T., and Coomáraswámy, A. K., Serendibite, a new borosilicate from Ceylon: *Mineral. Mag.*, vol. **13**, pp. 224–227, 1903.

Prior gives as a provisional formula: $10(Fe,Ca,Mg)O.5Al_2O_3 \cdot 6SiO_2 \cdot B_2O_3$ writing it, in an expanded form, as $6(Fe, Ca, Mg)SiO_3 \cdot 4MgAl_2O_4 \cdot 2AlBO_3$, "suggestive of a combination of aluminum borate with molecules having the composition of diopside and spinel, the two minerals with which serendibite is so intimately associated." The formula derived from the analysis of the New York serendibite, namely $3Al_2O_3 \cdot 4MgO \cdot 2CaO \cdot B_2O_3 \cdot 4SiO_2$, which is somewhat simpler than Prior's formula, can be similarly expressed, namely $2[CaO \cdot MgO \cdot 2SiO_2]+2[MgO \cdot Al_2O_3]+1[Al_2O_3 \cdot B_2O_3]$ or 2 diopside + 2 spinel + 1 jeremejevite.

Ferrous iron replaces a small part of the magnesia. The serendibite from New York contains 90 per cent of the iron-free magnesia compound and that from Ceylon contains 85 per cent.

Spinel and Unknown Mineral B

The analyses of the blue spinel and the white unknown mineral B, associated with the serendibite from New York, are shown below, two analyses on different samples of the unknown white mineral being given. The silica present is due to admixed diopside.

Table 3. Analysis of Blue Spinel and of White Unknown Mineral (B) Associated with Serendibite from New York

	Spinel	Unknown mineral (B)	
Insoluble residue	0.86	0.81	0.41
SiO_2	4.23	2.22	7.15
Al_2O_3	60.63	24.51	26.73
FeO	4.57	[a]	Not det.
CaO	0.29	[b]	3.73
MgO	24.24	29.82	27.84
	94.82		

[a] Several per cent.

[b] Determination lost.

Deducting diopside (based on the silica content) from the two analyses of the unknown white mineral, the following results are obtained:

		Ratios		Ratios
Al_2O_3	24.51	0.24	26.73	0.26
CaO	.....		0.36	
MgO	29.07	0.72	25.43	0.63

These figures suggest that in the unknown mineral, the ratio of Al_2O_3 to MgO is about 1:3 or 2:5. Other elements (such as boron) were not tested for and at present no suggestion can be made as to the identity of the mineral. It is definitely not a silicate.

THE CHEMICAL COMPOSITION OF NOSELITE AND HAÜYNE

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R. Brauns in his important study of *die Mineralien der Niederrheinischen Vulkangebiete* (7) states that the composition of noselite is: $6(NaAlSiO_4) \cdot Na_2SO_4$, and of haüyne: $X(NaAlSiO_4) \cdot CaSO_4$. (Excerpt: "Allgemein also enthielte der Laacher Haüyn das Nephelinsilikat verbunden in nicht festem Verhältnis mit $CaSO_4$.")

These formulae are purely empirical and represent a logical conclusion arrived at by inspection of analyses of natural minerals.

In the present paper new experimental data will be discussed, partly verifying, partly clarifying the aforementioned formulae. A complete study of the crystal structures of noselite, haüyne, and sodalite has also been carried out, but only data pertinent to the chemistry of these minerals will be considered here.

NOSELITE ($Na_8Si_6Al_6O_{24} \cdot SO_4$)

There should be little doubt that the true formula for noselite is: $6(NaAlSiO_4) \cdot Na_2SO_4$. All analyses are in fair agreement with this formula, and nothing really supports the older view of a more highly sulfurated molecule: $3(NaAlSiO_4) \cdot Na_2SO_4$. In spite of this fact the latter formula is apparently the one enjoying general acceptance.

In order to establish the true formula definitely, syntheses were made by mixing glass of the composition $NaAlSiO_4$ with Na_2SO_4 corresponding to the ratios 6:1 and 3:1. Heated for *ca.* 150 hours around 800° the mixture corresponding to the ratio 6:1 became practically homogeneous (isotropic with $n = 1.492$), whereas the mixture 3:1 was still nonhomogeneous. Thus in the first mixture the reaction product seemed to be only noselite, and this was also verified by an x-ray analysis of the powder whose diffraction pattern was almost identical with that of natural noselite. In the x-ray spectrogram of the second mixture all the lines belonging to the noselite structure were present, but in addition a few extra lines were encountered which could be identified as belonging to the high-temperature modification of Na_2SO_4. Beyond any possible doubt, therefore, the formula of noselite has been established as $Na_8Al_6Si_6O_{24} \cdot SO_4$.

It is proposed that the formula be written as above and not like a double salt, $6(NaAlSiO_4)\cdot Na_2SO_4$, for *x*-ray studies of the atomic arrangement have shown that the two Na-ions which in the double salt formula are united to the SO_4-group occupy positions which are structurally identical with those of the other Na-ions. This way of writing the formula does have mnemonic advantages but should be avoided because it might be construed as having a structural analogue.

HAÜYNE $[(Na, Ca)_{4-8}Al_6Si_6O_{24}\cdot(SO_4)_{1-2}]$

In the noselite molecule soda can be partly replaced by lime, and if the lime content exceeds *ca.* 6 per cent the mineral is called haüyne. Thus the natural haüyne is not a chemical compound but a mixed crystal with noselite as one end member and some Ca-bearing silicate, or silicates, as other end members.

A mixture of the constituent oxides will not, when heated under atmospheric conditions, combine to form haüyne, but the chief reaction products are usually noselite and anorthitic feldspar. No elaborate experiments for making haüyne (for instance, in bombs) were attempted, however, since it can be shown that *x*-ray diffraction data from natural haüyne suffice for establishing the true chemical formula.

X-ray diffraction data from noselite and haüyne are on record (8), (9), and new data were obtained during the course of this study. The two minerals exhibit very similar crystal structures. They both are isomorphous with the space group T_d^1; the lattice spacings are slightly larger in haüyne than in noselite, but otherwise they have practically the same atomic arrangement.

The length of the edge of the unit cube is, for noselite: $a_0=9.04$Å (artificial material); for haüyne: $a_0=9.11$ Å (*ca.* 10 per cent CaO).

These structures can be thought of as packings of large oxygen ions containing the smaller cations; the index of refraction of the crystal will depend upon how tightly the ions are packed. The unit of structure contains in the case of noselite 28 oxygen ions (and 21 cations). This is in agreement with the low index of refraction of noselite, and since haüyne has almost the same refractive index and lattice spacings, the unit of its structure also must contain nearly the same number of ions. For this reason, if for no other, the frequently postulated formula for haüyne: $6(NaAlSiO_4)\cdot 2CaSO_4$ (leading to 32 oxygen ions in the unit cube) has to be discarded. Furthermore, all analyses save one (4) show a decidedly lower content of CaO and SO_3 than this formula.

A possible formula for haüyne must fulfill the following two requirements:

(1) It should be derivable from a structure isomorphous with that of noselite. (2) It should lead to a unit of structure containing exactly or nearly the same number of ions.

X-ray studies have established the fact that in noselite the ions occupy the positions shown in Table 1, line I. A possible chemical composition of the hypothetical end member of the noselite-haüyne series is given under II′ (Table 1). Any mixed crystal between I and II′ would then have the formula $(Na, Ca)_{4-8}Al_6Si_6O_{24}\cdot SO_4$. An inspection of the analyses of haüyne shows, however, that the calcium sulfate content usually is slightly higher than that demanded by this formula. It seems, therefore, as if to a limited extent, additional Ca and SO_4 ions can be built into the haüyne structure. The reason for this incorporation must be sought in the fact that haüyne crystals with considerable silicate II′ in them would display an extremely open structure. The pure noselite has also an open "framework" within which there are empty spaces and passages, and as seen from Table 1, the eight sodium ions in noselite, I, are replaced by only four calcium ions in II′, thus causing the open "framework" type of structure to become still more pronounced.

Table 1. Comparison of the Chemical Composition of Noselite, Haüyne, and Sodalite

	1a	1b	4a				12f		12g+12g
Noselite I	—	S	O_4	—	Na_4	Na_4	Al_6	Si_6	O_{24}
II′	—	S	O_4	—	—	Ca_4	Al_6	Si_6	O_{24}
Haüyne II″	. . . .	$(SO_4)_{1-2}$. . . .			$(Na,Ca)_{4-8}$		Al_6	Si_6	O_{24}
Sodalite III	Cl	Cl	–	–	Na_4	Na_4	Al_6	Si_6	O_{24}

Although there is room for two $(SO_4)^{--}$-ions in the unit cube of noselite (in analogy with the two Cl^+-ions in sodalite, see table), only one is actually present as there are in the structure no more electropositive valences available which could unite with an additional $(SO_4)^{--}$-ion. But in a calcium-bearing mixed crystal where Na^+ and Ca^{++} replace each other freely (because they have nearly the same ionic radius) the sum of the electropositive valences may be such that more than one $(SO_4)^{--}$-ion per unit of structure can be bound; the upper limit will be two, as there are not more than two positions available in the lattice. The general formula for the mixed crystal will thus be: $(Na, Ca)_{4-8}Al_6Si_6O_{24}(SO_4)_{1-2}$ where the number of the $(SO_4)^{--}$-ions depends upon how many electropositive valences are available, which again is determined by the Na:Ca ratio.

It should be added that only in this way can the atomic arrangement of haüyne be explained; no other chemical formula seems capable of explaining the observed intensities of the *x*-ray reflections.

It is noteworthy that the haüyne series in some respects is similar to the nepheline series, for if the silicates I and II′ are written: $3(Na_2Al_2Si_2O_8) \cdot Na_2SO_4$ and $3(CaAl_2Si_2O_8) \cdot CaSO_4$ respectively, it is seen that the molecule $Na_2Al_2Si_2O_8$ (nepheline molecule) is partly replaced by $CaAl_2Si_2O_8$ (anorthite molecule), just as has been found by Bowen (3) to be the case in crystals of nepheline. The same mechanism that conditions the unusual replacement of Na_2O by CaO in nepheline is therefore probably instrumental in haüyne also.

There is in all probability no complete series of solid solution between the silicates I and II′. Most natural haüynes carry about 60 per cent of silicate I (noselite silicate).

The following table gives the most recent analyses of haüyne recalculated in terms of the above-mentioned silicates.

Table 2. Recalculation of Haüyne Analyses

	Haüyne from Monte Vulture (11)	Average value of haüyne from Laacher See (7)
	Mol. prop.	Mol. prop.
SiO_2	545	585
Al_2O_3	271	277
CaO	170	163
Na_2O	168	244
K_2O	58	
SO_3	100	152
Cl	11	
CO_2	10	
	$[Na_{5.0}Ca_{1.9}]Al_6Si_6O_{24}(SO_4)_{1.3}$ K_2O is reckoned with Na_2O and Cl and CO_3 are reckoned with SO_4	$[Na_{5.1}Ca_{1.7}]Al_6Si_6O_{24}(SO_4)_{1.5}$

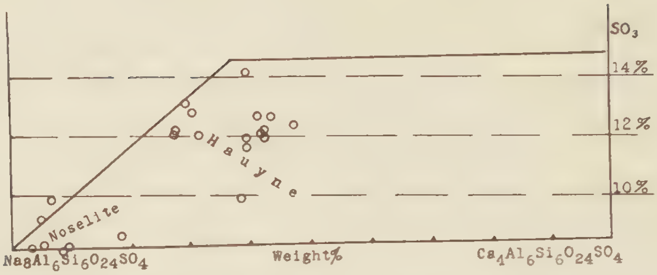

FIG. 1. Chemical composition diagram of noselite and haüyne [$(Na, Ca)_{4-8}Al_6Si_6O_{24}(SO_4)_{1-2}$]. Abscissa, ratio $Na_2O:CaO$. Ordinate, degree of sulfuration.

The crystal structure of these minerals requires that the composition lie within the blocked area, and the actual analyses (small circles in the diagram) confirm this.

SUMMARY

Noselite can be regarded as a chemical compound the composition of which can be expressed by the following formula: $Na_8Al_6Si_6O_{24} \cdot SO_4$.

Haüyne is a mixed crystal produced by the sodium in noselite being partly replaced by calcium and extra $(SO_4)^{--}$-groups simultaneously being built into the crystal lattice. The general formula for such a mixed crystal is: $(Na, Ca)_{4-8}Al_6Si_6O_{24} \cdot (SO_4)_{1-2}$.

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(With informatory notes)

1890.

(1) BRÖGGER, W. C., AND BÄCKSTRÖM, H., Die Mineralien der Granatgruppe: *Zeitschr. f. Krist.*, **18**, 209–276, 1890.

Formulae for noselite and haüyne as proposed by Rammelsberger, Clarke, Groth, and others were discussed. New formulae were set forth: noselite: $Na_4\ Al(NaSO_4)\ Al_2 \cdot (SiO_4)_3$ and haüyne: $Na_2Ca\ Al(NaSO_4)\ Al_2(SiO_4)_3$. These formulae are still generally accepted. The crystallographic relationship to helvite, which at that time seemed utterly fortuitous, was suggested; this was later verified through my x-ray studies (*Norsk Geol. Tidsskr.* **9**, 40, 1926) and can now be explained as a consequence of the radius ratios of the constituent ions. All these minerals were regarded as belonging to the garnet family.

1899.

(2) MOROZEWICZ, J., Experimentelle Untersuchungen über die Bildung der Minerale im Magma: *Tschermak's Min. Petr. Mitt.*, **18**, 105–240. 1899.

The correct formula for noselite, $6(NaAlSiO_4) \cdot Na_2SO_4$, was established based on synthetic studies; the same formula has since been confirmed by various investigators (6), (7), (8), (10); but owing to the conservatism peculiar to the science of mineralogy it has failed, so far, to become generally accepted. M. further explained haüyne as a mixed crystal of noselite and the silicate

$2(CaAl_2Si_2O_8)CaSO_4$, which is indeed very close to the truth. It is unfortunate that this fine piece of work has received so little attention. References to the earlier literature are given.

1912.

(3) BOWEN, N. L., The binary system $Na_2Al_2Si_2O_8$ (nephelite-carnegieite)-$CaAl_2Si_2O_8$ (anorthite): *Am. J. Sci.*, **33**, 551, 1912.

The existence of mixed crystals between $Na_2Al_2Si_2O_8$ and $CaAl_2Si_2O_8$ was established.

1912.

(4) PARRAVANO, N., Sulla composizione chimica della Haüynite dei Colli Albani: *Rendic. R. Accad. dei Lincei*, (5) **21**, 631, 1912.

Analysis of haüyne with high content of $CaSO_4$.

1920.

(5) JAKOB, J., Zur Konstitution der Silikate: *Helvetica Chemica Acta* III, 683 ff., 1920.

The old formulae by Brögger and Bäckström were maintained.

1921.

(6) GOSSNER, B., Zur chemischen Konstitution der Silikate: *Centralblatt f. Min.*, **1921**, p. 513; **1922**, p. 193 ff.

Morozewicz's formula for noselite was re-established. Brögger and Bäckström's formula for haüyne was maintained.

1922.

(7) BRAUNS, R., Die Mineralien der Niederrheinischen Vulkangebiete, *Stuttgart*, **1922**.

Morozewicz's formula for noselite was re-established; to haüyne was given the formula as stated in the beginning of the present paper.

1927.

(8) BARTH, T. F. W., Die Pegmatitgänge im Seilandgebiete: *Vid. Akad. Skr. Oslo*, **1927**, No. 8.

The section: "Zur Konstitution der Sodalitmineralien" (p. 75 ff.) is a preliminary note on the results given in the present paper. Based on X-ray studies Morozewicz's formula for noselite was re-established, and haüyne was regarded as a mixed crystal of noselite and the silicate: $3(CaAl_2Si_2O_8)\cdot CaSO_4$.

1929.

(9) JAEGER, F. M., Constitution and Structure of Ultramarine: *Akad. Amsterdam Versl.*, **32**; *Trans. Faraday Soc.*, **25**, 320, 1929.

X-ray data on noselite and haüyne.

1930.

(10) BORGSTRÖM, L. H., Chemismus der Mineralien der Sodalith- und der Cancrinitgruppe: *Zeitschr. f. Krist.*, **74**, 117, 1930.

Morozewicz's formula for noselite was re-established. Brögger and Bäckström's formula for haüyne was maintained.

1931.

(11) RITTMANN, A., Gesteine und Mineralien von Monte Vulture: *Schweiz. Min. Petr. Mitt.*, **11**, 250, 1931.

New analysis of haüyne.

FERROTREMOLITE, OXYHORNBLENDE, AND TOURMALINE

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1. Ferrotremolite

The formula of tremolite has recently been established by the *x*-ray studies of Warren[1] as $H_2Ca_2Mg_5Si_8O_{24}$. It has been the practise of mineralogists for many years to consider that a monoclinic amphibole of this type should be called tremolite if it was nearly or quite colorless, while similar material of a green color has been called actinolite. Expressed in chemical terms this means that such amphiboles with less than about 3 weight percent FeO or 10 molecular percent $H_2Ca_2Fe_5Si_8O_{24}$ are called tremolite, while those with more iron than this are called actinolite. Such a practise was satisfactory as long as iron-rich members of this series were unknown, but at present so-called "actinolites" have been described with 75 and even 95 molecular per cent of the iron molecule.[2] Therefore a name for this end member of the series is needed. It seems undesirable and unreasonable to give the same name to the pure iron end-member as is given by all to a mineral containing only 15 molecular percentage of that molecule. Accordingly "actinolite" is not satisfactory as a name of this substance. Is it not fitting to call it *ferrotremolite?*

2. Oxyhornblende

Barnes[3] has recently demonstrated quite completely that ordinary hornblende can be changed artificially to a condition similar to that found in so-called "basaltic hornblende" without destruction of the space lattice. He has proved that the change in properties is due to an oxidation of the ferrous iron of the mineral to the ferric state, a change which takes place readily in air at about 800°C; this change can be reversed by heating the mineral to the same temperature in an atmosphere of hydrogen. Nevertheless, this oxidation of ferrous iron is not produced by addition of oxygen from the air, but rather by a loss of hydrogen (not water) and rearrangement of valence bonds of oxygen atoms already in the mineral. Natural "basaltic hornblende" differs from hornblende artificially changed in that the oxidation of the ferrous iron is generally partial rather than complete, but the essential feature is oxidation in both cases. It is well known that dark brown hornblendes are not confined to basalts, but are found in all kinds of volcanic rocks so that the name "basaltic hornblende" is clearly

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[1] *Zeit. Kryst.*, **LXXII,** 1929, p. 42.

[2] W. Kunitz, *N. Jahrb. Min., Bl. Bd.*, **LX,** 1930, p. 171; A. N. Winchell, *Am. Mineral.*, **XVI,** 1931, p. 250.

[3] *Am. Mineral.*, **XV,** 1930, p. 393.

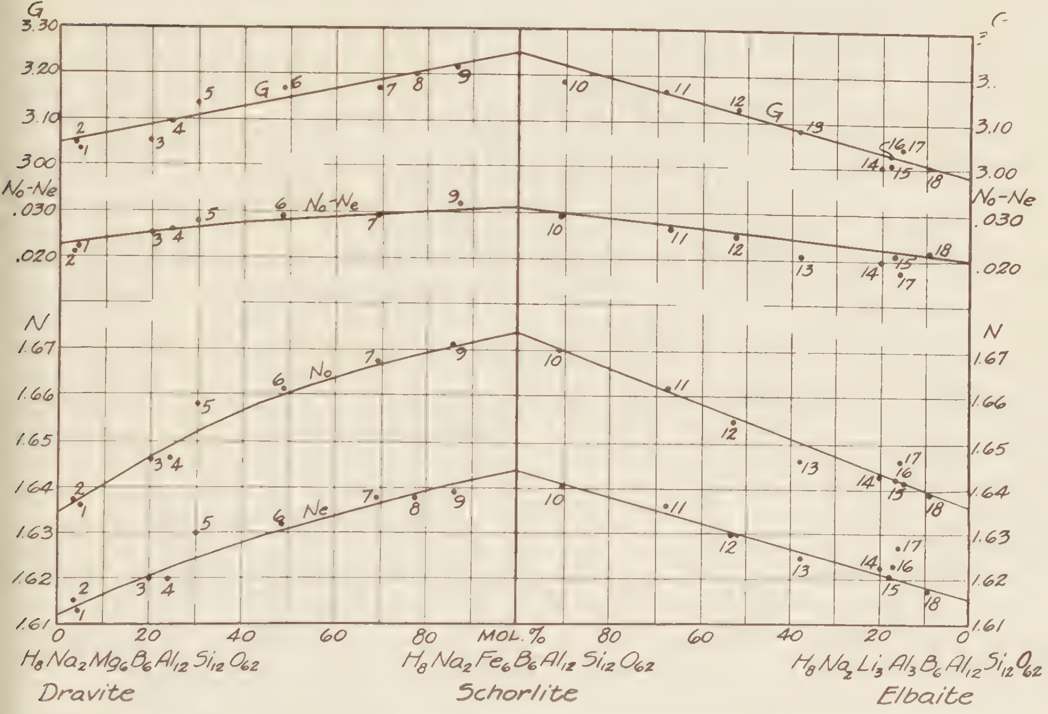

FIG. 1. Relations between composition and properties in the dravite-schorlite and schorlite-elbaite series.

not well chosen. The writer would suggest that such amphiboles may well be called *oxyhornblendes*. Some rare dark brown hornblendes contain very little ferric iron, but, like the others, they contain very little hydrogen and therefore have valence bonds of oxygen (in other cases united with hydrogen) available for other elements. Apparently such a condition permits the presence of considerable titanium, as found in *kaersutite*.

3. TOURMALINE

Kunitz[4] has recently published an important study of the chemical composition and optic properties of tourmaline. From a study of twenty new analyses (and some old ones) he derived a complex formula which may be generalized as follows:—$H_8Na_2R_6Al_{12}B_6Si_{12}O_{62}$. Nearly at the same time Machatschki[5] published the results of an x-ray study of tourmaline which led to a formula as follows: $H_xNa_2(R''+R''')_{18}B_6Si_{12}O_{62}$. These two formulas, obtained quite independently by entirely different methods, are so nearly alike that it is very probable that they both represent a very close approximation to the truth.

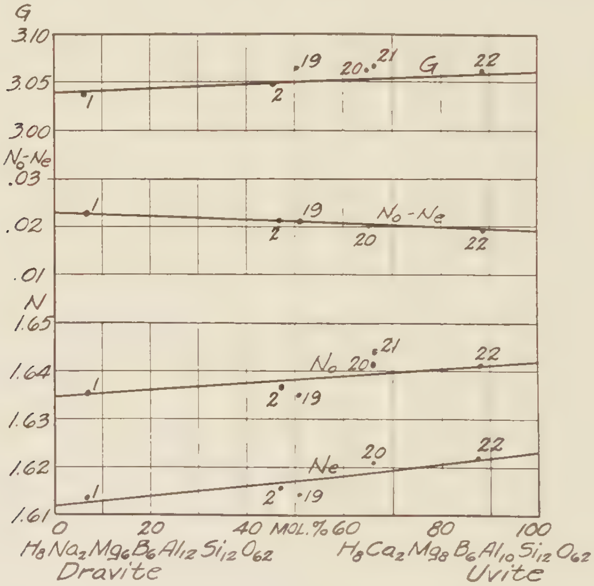

FIG. 2. Relations between composition and properties in the dravite-uvite series.

Kunitz also prepared graphs showing the relation between optic properties and chemical composition in certain binary series of the tourmaline system, but the writer has found some difficulties in attempting to correlate these graphs with the analyses. Therefore new graphs have been prepared with the assistance of Mr. L. G. Trowbridge, and they are shown in Fig. 1. The magnesium, iron, and lithium types (dravite, schorlite, and elbaite) might be shown in one triangular diagram, but actual examples of the dravite-elbaite series as well as examples well within the triangle are not now known; accordingly, the binary diagrams are better adapted to show present data.

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[4] *Chem. Erde*, **IV**, 1929, p. 208.

[5] *Zeit. Kryst.*, **LXX**, 1929, p. 211; Ca included with Na.

The sodium-calcium variation in tourmaline is entirely independent of the magnesium-iron-lithium variation, its effects on the optic properties of magnesium-rich tourmalines are shown in Fig. 2. Its effects on other tourmalines can be shown conveniently in a diagram having chemical variations of two kinds on two coordinates, as illustrated in Fig. 3. In this diagram some analyses are used which can be calculated into the molecules used only by assuming some replacement of MgSi by AlAl,[6] and some others are used which seem to require the presence of more Li_2O than reported in the chemical analyses. Also, manganese, ferric iron, and titanium atoms are considered as equivalent to ferrous iron atoms. Some difficulties in the interpretation of tourmaline analyses may be due

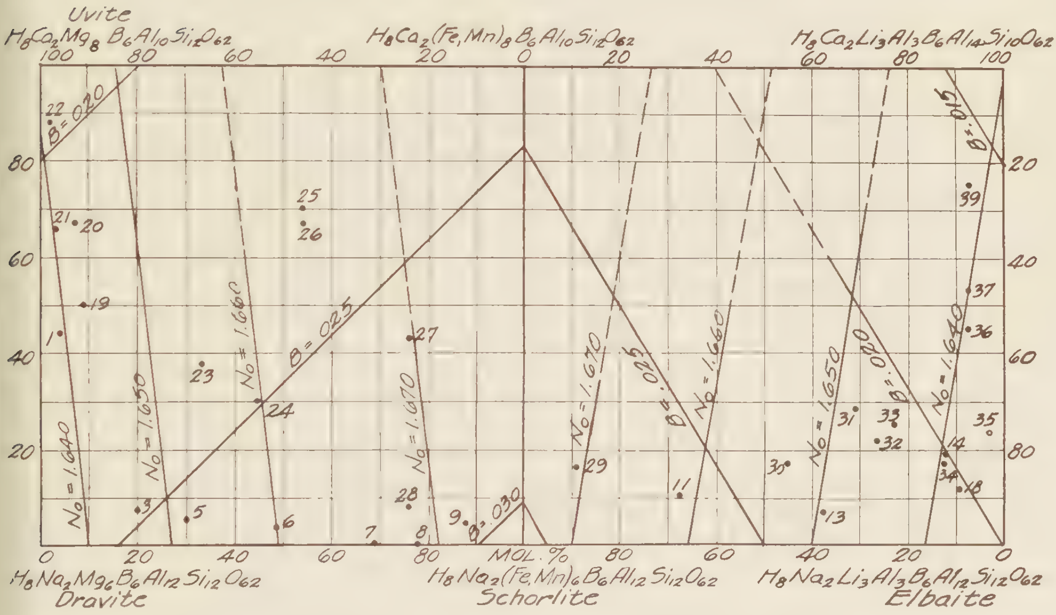

FIG. 3. Relations between composition and optic properties in some tourmalines.

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[6] This change seems to have very little effect on the optic properties.

to changes in the composition of tourmaline after formation, a process the occurrence of which is indicated by the recent work of Ward.[7]

A series is now known from the lithium tourmaline (elbaite) to about 50 molecular per cent of the manganese tourmaline, which has been named *tsilaisite*. Unfortunately this series can not be distinguished at present from the lithium-iron tourmalines by its indices of refraction. The magnesium-iron tourmalines (the dravite-schorlite series) vary from light brown at the magnesium end to dark brown, dark green, or dark blue, to black with 25 to 100 molecular percent of the iron molecule.

It seems almost superfluous to add that no claims of high accuracy are made for these diagrams, though they represent present data fairly well. However, they assume that the optical effects of ferric iron, manganese and titanium atoms are the same as those of ferrous iron atoms, which is only approximately true, and they disregard entirely some other variations in composition, especially, substitution of AlAl for MgSi, and of F for OH, which unquestionably produce some effects upon the optical properties.

References for the Tourmaline Diagrams

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2. Uvite, Gouverneur, N. Y. W. Kunitz: *op. cit.*, p. 214, No. 5; p. 217, No. 9.
3. Tourmaline, Posten Sonjo, E. Africa. E. A. Wülfing and K. Becht: *Sitz. Akad. Wiss. Abh.*, **20**; *Zeit. Kryst.*, **LVII**, 1922, p. 332.
4. Tourmaline (black), Spessart. W. Kunitz: *op. cit.*, p. 214, No. 2; p. 217, No. 2.
5. Tourmaline (black), Bamle. W. Kunitz: *op. cit.*, p. 214, No. 3., p. 217, No. 3.
6. Tourmaline (black), Pedretto. W. Kunitz: *op. cit.*, p. 214, No. 8; p. 217, No. 4.
7. Schorlite, Hörlberg. W. Kunitz: *op. cit.*, p. 214, No. 6; p. 217, No. 6.
8. Schorlite, Chursdorf. W. Kunitz: *op. cit.*, p. 214, No. 7; p. 217, No. 7.
9. Schorlite, Epprechtstein. W. Kunitz: *op. cit.*, p. 214, No. 9; p. 217, No. 8.
10. Schorlite, Eibenstock. W. Kunitz: *op. cit.*, p. 215, No. 5; p. 222, No. 7.
11. Indigolite, Ural. W. Kunitz: *op. cit.*, p. 215, No. 3; p. 222, No. 5.
12. Tsilaisite, Nertschinsk. W. Kunitz: *op. cit.*, p. 215, No. 9; p. 222, No. 11.
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16. Rubellite, Penig. W. Kunitz: *op. cit.*, p. 215, No. 7; p. 222, No. 1.
17. Tourmaline (pale green), Mesa Grande, Calif. W. T. Schaller: *Zeit. Kryst.*, **LI,** 1912, p. 321.
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[7] *Am. Mineral.*, **XVI,** 1931, p. 145.

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21. Tourmaline (aver. brown), Ceylon. E. A. Wülfing and K. Becht: *op. cit.*
22. Tourmaline (pale brown), Ceylon. E. A. Wülfing and K. Becht: *op. cit.*
23. Tourmaline (black), Drummerstown, Vt. G. W. Ward: *Am. Mineral.*, **XVI,** 1931, p. 145, No. 38.
24. Tourmaline (black), Wickes, Mont. G. W. Ward: *op. cit.*, No. 23. This is the tourmaline described by H. V. Winchell and A. N. Winchell: *Econ. Geol.*, **VII,** 1912, p. 287.
25. Tourmaline (black), St. Lawrence Co., N. Y. G. W. Ward: *op. cit* , No. 70.
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27. Tourmaline (black), Moriah, Essex Co., N. Y. G. W. Ward: *op. cit.*, No. 179.
28. Tourmaline (black), Custer, S. Dak. G. W. Ward: *op. cit.*, No. 79.
29. Tourmaline (black), Thousand Islands, G. W. Ward: *op cit.*, No. 158.
30. Tourmaline (black), Tsilaisina, Madagascar. Duparc, Wunder and Sabot: *op. cit.*, pp. 389–395, No. 14.
31. Tourmaline (greenish brown), Tsilaisina, Madagascar. Duparc, Wunder and Sabot: *op. cit.*, pp. 389–396, No. 11.
32. Tourmaline (pale yellow), Tsilaisina, Madagascar. Duparc, Wunder and Sabot: *op. cit.*, pp. 389–396, No. 8.
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35. Tourmaline (red), Himalaya mine, Calif. W. T. Schaller: *op. cit.*
36. Tourmaline (pink), Tsilaisina, Madagascar. Duparc, Wunder and Sabot: *op. cit.*, pp. 389–396, No. 7.
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38. Rubellite (pink), Maroando, Madagascar. Duparc, Wunder and Sabot: *op. cit.*, pp. 388–389, No. 5.
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METHOD OF MAKING SYNTHETIC MINERALS FOR POLISHED SURFACE STUDY*

G. M. SCHWARTZ

INTRODUCTION

In carrying on experimental work involving argentite and chalcocite it was found necessary to make synthetic silver sulphides because of the scarcity of even approximately pure argentite. It was highly desirable that the synthetic argentite be obtained in a form permitting study of the material on polished surface previous to experimental work. It occurred to the writer that ordinary chemically precipitated silver sulphide could be compressed into a massive substance resembling natural argentite. The method described below resulted from experiments in making argentite and it was then applied to several of the common soft sulphides. The desirability of checking etch tests on chemically pure material is evident and the method is presented here in the hope that others will find it useful. For experimental work on some of the rarer minerals it furnishes a source of material which would otherwise be unobtainable.

The writer is indebted to Dr. R. B. Ellestad of the Rockefeller National Laboratory for Rock Analysis for the preparation of the chemical precipitates. Mr. Maynard M. Stephens assisted throughout the experimental work.

PREPARATION OF THE SULPHIDES

The sulphides of lead, mercury, antimony and bismuth were precipitated with hydrogen sulphide from aqueous solutions of the chlorides, slightly acidified with HCl, at a temperature of about 90°C. The sulphides of silver and copper were precipitated from hot solutions of the sulphates, slightly acidified with sulphuric acid. Except in the case of silver sulphate the concentrations of the solutions used were such as to yield ten grams of sulphide from a liter of solution. With silver sulphate a greater dilution was necessary, owing to the low solubility of silver sulphate. The solutions were well stirred during precipitation and in all cases hydrogen sulphide was passed in until precipitation was complete. The precipitates were well washed, first by decantation, and then on the Büchner funnel used for filtering. Hot water containing a little hydrogen sulphide was used for washing the lead and copper sulphides; for the others hot water alone was used. The sulphides obtained in this manner were partially dried in lump form. Following this they were powdered in a mortar and dried at 105°C for 12 hours.

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* The work on which this paper is based was aided by a grant from the research funds of the Graduate School of the University of Minnesota.

APPARATUS

Pressure was applied by a hydraulic press manufactured by Fred S. Carver of New York, and capable of supplying pressure up to 16,000 pounds per square inch.

For a mold, a cylinder manufactured by the same firm was adapted as shown in Fig. 1. A smaller and somewhat lighter cylinder was also used but this failed to withstand the pressures without troublesome distortion. A cylinder with a smaller inside diameter would be preferable; about 3/4 inch would seem a desirable size.

For heating the cylinder while the pressure was being applied the outside was insulated with asbestos paper and wound with nichrome wire embedded in a mixture of alundum cement and asbestos. With suitable rheostats the desired temperature may be obtained. Very high temperatures could not be used without a specially designed mold because of the effect of high temperature and stress on steel.

In the case of minerals treated with pressure alone the compression was continued from two to six hours. When heat was used both heat and pressure were applied from one to two hours.

SYNTHETIC MINERALS PRODUCED

The following synthetic minerals were produced: argentite, covellite, galena, bismuthinite, metacinnabarite, metastibnite, and stibnite. It is evident that the softer, more sectile minerals which lack pronounced cleavage give the best results at moderate pressures and temperatures. Thus, of the minerals noted above, argentite gave the best results with pressure alone. Galena, covellite, bismuthinite and stibnite gave poor results with only pressure but yielded very satisfactory material by combined heat and pressure.

Most of the synthetic minerals are very fine grained but grains of covellite up to four tenths of a millimeter were measured. The synthetic galena is fine grained like natural steel galena. Stibnite had a well defined granular structure just visible at a magnification of eighty diameters.

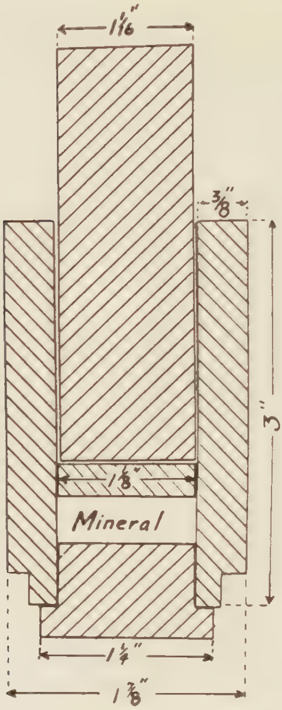

FIG. 1. Sketch of steel cylinder used for compressing chemically precipitated sulphides into solids. Two-thirds natural size.

ARGENTITE

Argentite produced the most successful synthetic mineral presumably because of its soft and sectile nature. Compression at 16,000 pounds produced a material which is remarkably like the natural material in general appearance. The briquet is strong and will stand rough handling and takes an excellent polish.

The etch reactions on the polished surface are compared below with those given by Short in United States Geological Survey, *Bulletin* 825.

Light etch.[1] In four seconds the material forms the characteristic spots seen in natural argentite. On longer exposure, turns black and a brown to milky white sublimate is formed on the objective.

This synthetic argentite has been used in a great number of experiments and has proven a perfectly satisfactory substitute for the natural material.

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[1] Stephens, Maynard M., Effect of light on polished surfaces of silver minerals: *Am. Mineral.*, vol. **16**, pp. 532–549, 1931.

ETCH TESTS ON ARGENTITE

Synthetic mineral	Natural Mineral (Short)
HNO_3, slight brownish fume reaction.	Fumes tarnish.
HCl, strong fume reaction.	Fumes tarnish; halo does not wash off.
KCN, quickly darkens, brings out fine structure.	Stains differentially black and brings out structure.
$FeCl_3$, quickly iridescent.	Quickly stains black.
Polarized light, isotropic.	Isotropic or anomalous anisotrophism.

GALENA

Precipitated PbS under compression of 16,000 pounds per square inch forms a compact gray briquet which remains very soft and rubs off on handling, about like graphite. When heated to about 200°C under compression a briquet is formed which closely resembles steel galena. It takes an excellent polish and the color tests compare with Short's tests as follows:

ETCH TESTS ON GALENA

Synthetic mineral	Natural Mineral (Short)
HNO_3, effervescence; turns black.	Effervesces and turns black.
HCl, quickly turns dark; iridescent around edge.	Tarnishes iridescent.
KCN, Negative.	Negative.
$FeCl_3$, turns gray to iridescent.	Stains iridescent.
Polarized light, isotropic.	Isotropic.

COVELLITE

Chemically precipitated CuS is a soft, dirty green powder which does not much resemble natural covellite. Compression of this material at 16,000 pounds per square inch for several hours yielded a rather brittle briquet which has the typical covellite blue on the outside, but on the inside remains somewhat greenish. Application of compression and heat (16,000 pounds per square inch and temperature of 200°C) to this material results in a much more compact cake which is blue throughout and resembles natural cavellite in all external appearances. The etch tests compare with Short's tests as follows:

Etch Tests on Covellite

Synthetic mineral	Natural mineral (Short)
HNO_3, negative, effervescence in pores.	Negative.
HCl, negative.	Negative.
KCN, quickly dark brown to black.	Stains black.
$FeCl_3$, negative.	Negative.
Polarized light, strong anisotrophism.	Strong anisotrophism.

Stibnite and Metastibnite

Sb_2S_3 when precipitated with hydrogen sulphide from an aqueous solution of antimony chloride has an orange red color and the corresponding natural mineral, which is very rare, is known as metastibnite. This material when compressed at 16,000 pounds pressure assumes a dull red color, is very porous and scales to such an extent when moistened that it cannot be polished. When metastibnite in powdered form is compressed by 16,000 pounds pressure and heated to about 200°C at the same time, it turns black and is compressed into a dense metallic material which is somewhat brittle. This takes an excellent polish, has low porosity with some peculiar curved cracks, evidently due to expansion when the pressure is released. The material is obviously stibnite and compares with Short's tests as follows:

Etch Tests on Stibnite

Synthetic mineral	Natural mineral (Short)
HNO_3, quickly dark to iridescent around edge; very slow effervescence.	Stains differentially iridescent, some varieties effervesce slowly.
HCl, slight fume reaction.	Fumes tarnish; some varieties negative.
KCN, slight gray tarnish.	Brings out scratches and sometimes stains slightly.
$FeCl_3$, negative; if left long time iridescent fume reaction.	Negative.
KOH, instantly brown and heavy yellow coat.	Instantly brown and gives yellow coating.
Polarized light, strong anisotrophism.	Very strong anisotrophism.

METACINNABARITE

When HgS is precipitated with hydrogen sulphide from an aqueous solution of the chloride a black amorphous material is formed. This material, when compressed at 16,000 pounds pressure, forms a compact, heavy, but brittle cake. This material corresponds exactly with the properties of meta-cinnabarite. If the precipitated material is subjected to the same pressure but at a temperature of 200°C, a material with a high metallic luster is produced which is somewhat harder than that formed by pressure alone.

This compares with Short's tests for meta-cinnabarite as follows:

ETCH TESTS ON METACINNABARITE

Synthetic mineral	Natural mineral (Short)
HNO_3, negative.	Negative.
HCl, negative.	Negative.
KCN, negative.	Negative.
$FeCl_3$, negative.	Negative.
Aqua regia, effervesces and turns black.	Effervesces and turns black.

The work of Allen and Crenshaw[2] indicates that cinnabar could be produced from metacinnabarite, but the temperatures required (400° to 500°C) are considerably higher than were used in the experiments reported here.

BISMUTHINITE

Bismuth sulphide when precipitated with hydrogen sulphide from an aqueous solution of the chloride is a black amorphous material, which on drying and grinding in a motar forms a granular powder. When compressed at 16,000 pounds for several hours the material forms a rather hard, but very porous briquet. Because of the porosity this material does not take a very good polish. The material when heated to 200°C, while under pressure, is very much less porous and more crystalline in appearance, and the polish is correspondingly better.

The etch tests are identical for both types and correspond with Short's tests as follows:

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[2] Allen, E. T., and Crenshaw, J. L. The sulphides of zinc, cadmium and mercury; their crystalline forms and modifications: *Am. Jour. Sci.*, vol. **34,** 4th ser., p. 378, 1912.

ETCH TESTS ON BISMUTHINITE

Synthetic mineral	Natural mineral (Short)
HNO_3, effervescence; quickly black.	Slow effervescence and stains black.
HCl, fume reaction and drop turns slight gray with suggestion of structure.	Fumes tarnish.
HCN, negative.	Negative.
$FeCl_3$, negative.	Negative.
$HgCl_2$, slight brown.	Stains light brown.
Slightly anisotropic	Strong anisotrophism.

CONCLUSION

The results described indicate that many synthetic minerals may be made by the method described, or by slight modifications. This method provides a source of chemically pure compounds which may be studied on polished surface and thus slight changes induced by natural or added impurities may be detected. The same method may be used to make intimate mixtures of two minerals as may often be desirable in experimental work. Possibly the cause of many variations in etch reactions may be discovered by work on material which is known to be chemically pure.

MINERAL COMPOSITION OF SANDS FROM MONONGAHELA, ALLEGHENY, AND OHIO RIVERS

BYRON F. KING, *West Virginia University.*

The region drained by the Monongahela, Allegheny and Ohio Rivers is underlain almost entirely by sedimentary rocks, and the alluvial sands in the rivers are therefore derived mainly from the weathering and erosion of these rocks. However, the fact that some of the area drained by the Allegheny and other northern tributaries of the Ohio has been glaciated while none of that drained by the Monongahela has been, might be expected to lead to some differences in the composition of these sands. It was to investigate these differences that the study described here was undertaken. The laboratory work was done at West Virginia University, Morgantown, West Virginia.

Sands were collected from old stream terraces, recent bar and beach deposits, the river channels, and in some few cases it was necessary to rely upon samples taken from the stock piles of sand companies dredging these rivers. It was possible to get a sample from the channel of the Cheat River from a barge which had been just previously loaded. In every case a representative portion of the sand was taken and analyses were made of only those sands of which the source and location were definitely known.

LIST OF SAMPLES

CHEAT RIVER—(Tributary of Monongahela River).
No. 3001—Stock Sand, McClain Sand & Gravel Co., Point Marion, Pa.
3002—Dredged Sand from Barge below Cheat Haven Dam, Pt. Marion, Pa.
3008—Flood Plain, near Kingwood, West Virginia.

MONONGAHELA RIVER
No. 3003—River bar, sample dug, East Millsboro, Pa.
3004—River bar, scooped sample, East Millsboro, Pa.
3009—Dunkard Creek, a tributary of Monongahela River.
3012—River bar near West Masontown, Pa.
3011—River terrace, Brown's Ferry, Pa.
3013—River terrace, Fairmont, West Virginia.
3017—Old river terrace, Star City, West Virginia.

ALLEGHENY RIVER
No. 3006—Stock sand, Allegheny Wharf Company, Pittsburgh, Pa.
3007—Channel sand, Freeport, Pennsylvania.

OHIO RIVER
No. 3005—Stock sand, McClain Sand Company of New Martinsville, W. Va.
3010—Fish Creek, tributary of Ohio River.

3014–15–16—Neville Island, Pittsburgh, Pennsylvania.
3018—Beach deposit at Dayton, Kentucky.
3019—Dredged sand, Florence, Indiana.

BEAVER RIVER
No. 3020—Terrace sand, East Moravia, Pennsylvania.
3021–22—River bar, East Moravia, Pennsylvania.

A representative portion of about 15 grams (Table 1) of the original sample was used in the following laboratory procedure. The sands were thoroughly washed several times with water, then a bath consisting of dilute hydrochloric and sulphuric acids was applied to clean the grains of any limonite coating or stains. After drying, the material was sieved through a half-millimeter sieve. The portion under ½ mm. in size was separated by means of bromoform having a specific gravity of 2.83. After each process the sands were weighed. Permanent slides of the light and heavy portions of these sands were made for later microscopic determination. Canada balsam was the imbedding medium.

TABLE I. MECHANICAL ANALYSIS OF SAMPLES USED

Sample Number	% of Minus ½ mm	% of Heavy	Deposit	Results of Acid Treatments
3001	61.0	0.57	Dredged	Limonite stain removed
3002	78.7	1.86	Dredged	“ “ “
3008	100.0	1.20	River bar	“ “ “
3003	92.7	2.80	River bar	“ “ “
3004	100.0	2.20	River bar	“ “ “
3009	46.7	0.50	Creek bar	“ “ “
3011	100.0	0.70	Terrace	“ “ “
3012	80.0	0.30	River bar	Carbonate min. removed
3013	60.0	0.05	Terrace	Limonite stain removed
3017	99.5	0.13	Terrace	“ “ “
3006	80.0	3.80	Dredged	Carbonate min. removed
3007	78.0	3.40	Dredged	“ “ “
3005	68.6	2.40	Dredged	Limonite stain removed
3010	90.0	0.70	Creek bar	Slight effervescence
3014	94.5	5.60	Island	Carbonate min. removed
3015			Island	Sample of glac. pebbles
3016	96.7	5.50	Island	Slight effervescence
3019	73.2	6.25	River bar	Carbonate min. removed
3020	98.5	4.3	Terrace	“ “ “
3021	77.5	17.2	River bar	Contaminated*
3022*	71.5	36.2	River bar	Contaminated*

* Of 36.2% heavy concentrate 74.5% is metallic-iron.

TABLE II

Number of Sample	Leucoxene	Brown Opaque	Ilmenite	Pyrite	Magnetite	Zircon	Sillimanite	Cyanite	Barite	Muscovite	Biotite	Tourmaline	Hypersthene	Garnet	Hornblende	Augite	Epidote	Calcite	Rutile	Titanite	Chlorite	Anatase	Brookite	Tremolite	Enstatite	Xenotime	Light Portions	Quartz	Orthoclase	Plagioclase	Microcline	Micro-perthite
3001	a	F	s	R	P	A				c		c																F	s			
3002	a	F	s		P	A				c		c																F	s			
3003	a	F	s		P	A				c	R	c							R		R	R	R					F	s		R	
3004	a	A	s	s	P	A				c		c		R					r							P		F			r	
3005	s	S	c		P	C	c	s		c		c	c	A	c	s	s	P	s	S								F	R			c
3006	C	r	c		X	C	c	s		s		s	c	A	c	s	s	P	S									F	c		r	c
3007	C	r	c		X	c	c	s	P	c		s	c	A	c	s				R	R			P				F	c	r	r	
3008	a	A			X	C				c	R	C							R									F				
3009	a	A	S	R	X	C				c		S		R					R							P		F	R			
3010	a	A	s		X	C				c		s																F				
3011	a	A			X	C			c	c		c		R					R			R						F				
3012	a	A	S	R	X	C	R			c		C	R	R														F	R			
3013	a	A			X	c						c																F				
3014	C	r	c		X	C	c	s	r	c	R		C	A	C	s	s	P	r	R				s	R			F	c	r	r	s
3015	Sample of Glacial Pebbles																															
3016	C	r	c		X	C	c	s	r	c	R		C	A	C	s	s	P	r	R				s	R			F	c	r	r	s
3017	F				X	F				c	r	c							P							P		F				
3018	Sample Contaminated																															
3019	c	s	C		X	C	c	s	s	c	P		C	A	C	s		c	r					c				F	c	s	s	c
3020	c	s	C		X	C	c	s	s	c			C	A	C	s		c	r					c				F	a	s	s	c

Prof. W. W. Watt's method of estimating as described by Prof. Milner.
F—Flood, A—Very abundant, *a*—Abundant, C—Very common, *c*—Common, *s*—Scarce, S—Very scarce, *r*—Rare, R—Very rare, P—Present, X—Not determined.
Amount of calcite determined by acid test, magnetite determined by magnet test.

In the microscopic determination of the mineral content of these sands it was found that all samples contained mostly quartz. In the light portions (Table 2) of the Allegheny and Ohio Rivers, calcite, orthoclase and plagioclase grains were present, while the Monongahela sands consisted almost entirely of quartz (Table 2) and shale particles.

In the heavy portions of all these river sands there were found an abundance and variety of minerals. Those of the Monongahela (Table 2) consisted of pure and impure leucoxene, zircon, muscovite, tourmaline, biotite (rare), ilmenite, and an occasional grain of rutile. These minerals are characteristic of sands derived from other sedimentary rocks.

The heavy portions (Table 2) of the Allegheny and Ohio River sands contained a much greater variety of minerals derived from both igneous and metamorphic, as well as sedimentary rocks. In order of importance they are: garnet, hypersthene, zircon, augite, sillimanite, hornblende, tourmaline, leucoxene, barite, ilmenite, cyanite, actinolite, epidote, muscovite, enstatite, biotite, titanite, chlorite, pyrite, and rutile. During the acid treatment the presence of calcite was noticed. By using a magnet magnetite was found present in all sands of the Ohio and Allegheny Rivers. The Beaver River samples were examined to compare the sands of deposits along a river which drains a region wholly of morainic material with those from a river draining an area of which only a fractional part is derived from moraines. A casual examination of these samples showed about 30% of the heavy portion to contain the same minerals as the Allegheny and Ohio River samples (Nos. 3005-6-7-14-19). The remaining 70 per cent was found to be metallic iron which was carried from the slag dumps found along this river. The light portions contained chiefly quartz and orthoclase feldspar with many of the quartz grains showing secondary growths. The heavy portions being contaminated by metallic iron they were not studied in detail.

It was found by these analyses that the sediments of the Allegheny and Ohio Rivers differ greatly from those of the Monongahela and Cheat in mineral composition. The minerals of the two latter named rivers are quite characteristic of a sedimentary rock region but those minerals from the Allegheny and Ohio show a more nearly direct derivation from igneous and metamorphic rocks. It is known that all of these rivers drain regions in which bed rock is of Paleozoic age. Although these rocks are of sedimentary origin

Table III. Mineral Analysis of Five Representative Samples

Minerals Present	Sample Number				
	3001	3004	3007	3014	3019
Total Grain Count	498	1764	885	1478	649
	Percent Present				
Brown opaque	62.4	39.0	7.10	37.3	19.8
Black opaque	4.6	1.8	12.3	10.3	15.1
Leucoxene	23.0	20.6	2.7	7.0	8.9
Zircon	8.4	32.6	2.2	6.3	5.2
Tourmaline	1.0	2.4	1.7	2.6	1.5
Garnet			52.0	2.9	21.2
Hornblende			8.7	16.7	6.1
Sillimanite			5.3	6.1	9.4
Hypersthene			3.4	2.2	2.3
Augite			1.5	1.6	2.4
Cyanite			0.9	1.1	1.5
Epidote			1.2	0.9	0.6
Muscovite	X	0.7	X	2.7	4.9
Titanite			1.1	0.7	X
Rutile	X	0.5	0.0	0.5	X
Pyrite	X	0.5	0.0	0.0	0.1
Tremolite			X	0.8	X
Enstatite			X	X	X
Barite			X	X	X
Xenotime		X			X
Biotite				X	X
Andalusite					X
Anatase				X	
Actinolite					X
Metallic iron		1.7			

X—Represents a count of less than 0.5%. Muscovite loss due to floating during washing.

we must not overlook the morainic deposits which were left in the northern parts of Pennsylvania and Ohio as the great ice sheet melted. This morainic material contains igneous and metamorphic debris which the glacier picked up and carried in its southward advance. Since these morainic deposits were the last to be formed and since they are covering the country rock, they must be the first to weather and be carried away as sediments. Although an abundance of igneous and metamorphic material (Table 3) is found in the heavy portions of these sands it should not be thought that they tend to make up the greater part of the total sand. In reality only about 4 per cent of the total combines to make the heavier concentrates, while approximately 95 per cent is quartz. Of the sands in the Monongahela and Cheat Rivers, less than 2.5 per cent comprises the heavy portion of the cleaned sand, while 97 per cent is quartz.

Minerals similar to those found in the Ohio River are carried by the Great Kanawha which has its head waters in the pre-Cambrian rocks of Western North Carolina, and flows westward to meet the Ohio at Point Pleasant, West Virginia. This river carries no new minerals of igneous derivation into the Ohio but slightly increases the abundance of those already found.

Another factor influencing the composition of the sands is the composition of the river water in which it occurs. The waters of the Monongahela drainage system are known to be contaminated by sulphuric acid. This acid in the water may account for the complete loss of calcite in the samples taken from this particular region and for its scarcity in the Ohio sediments. Calcite is found most plentifully in the Allegheny River sands.

The abundance of leucoxene (Table 3) is a noticeable factor to be considered in the comparison of these stream deposits. Pure and impure leucoxene is most abundant in the Monongahela and Cheat River sediments, and is found to diminish in importance in the Allegheny sands but is of a purer grade than in the other sands. The increased amount in the Ohio sands is caused by the large quantity carried in from the Monongahela. This abundance of leucoxene in the river sediments is not due to any action of the stream water for it is found to be plentiful in the rocks of this region.[1]

A great loss of minerals in the Cheat and Monongahela River sands can be accounted for by the difference in conditions of the rock mass of the area. These rocks are more weathered than those of the northern parts in Pennsylvania and Ohio. A greater part of the sediments of these rivers is from the residual soils caused by this increased weathering of the country rock.

Of the samples taken from stock piles it is to be considered that dredged material will not give the true size of grain nor the true mineral composition of the sands. While nothing is added to the sand there is a great loss of mineral content especially muscovite (Table 3). This is caused by much of the finer sand being washed away during the dredging process.

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[1] James H. C. Martens, Personal communication and comparison of our studies.

NOTES AND NEWS

NATIVE TELLURIUM FROM NORTHWEST OF SILVER CITY, NEW MEXICO

Gerald J. Ballmer, *Santa Rita, New Mexico.*

The writer has identified native tellurium as one of several minerals in vein material collected at a gold prospect located in Grant County, New Mexico, at a locality about 41 miles northwest of Silver City and 12 miles south-southeast of Mogollon.

The vein, which occurs as a fissure filling in quartz latite, is 12 inches wide and has been opened to a depth of about 135 feet. It is composed principally of quartz and fluorite, the other minerals noted being bismuthinite, pyrite, and tellurium. Assays show that the ore carries gold, but no more than a trace of silver, noteworthy amounts of which are present in the ores of the Mogollon district.

Many openings and cavities occur in the quartz of the vein. Some of these cavities are lined with druses of minute quartz crystals, others with several layers of pyrite, then filled with tellurium, and still others are filled with tellurium alone without the lining of pyrite. The tellurium occurs in irregular ovoid bodies of various sizes, the maximum measured being 18 mm. in length and 8 mm. in width. From the above description it appears that the first minerals to be deposited were quartz and fluorite, followed by a period of pyrite and quartz, and last of all tellurium. It is probable that the bismuthinite and gold are contemporaneous with the tellurium.

Examined under the microscope the section shows the tellurium as a tin-white mineral with metallic luster and strongly marked anisotropism. The hardness of the mineral is approximately B of the standard scale, and a careful determination shows its specific gravity to be 6.188.

Etching tests gave the following results which check with those recorded by Davy and Farnham but not entirely with Short's table which shows that HCl fumes tarnish the polished surface.

HNO_3 (1:1), effervesces vigorously and stains dark gray.
HCl (1:1), negative.
KCN (20%), negative.
$FeCl_3$ (20%), slowly tarnishes brownish gray.
KOH (40%), negative.
$HgCl_2$ (5%), negative.

The writer is indebted to Mr. J. J. Jones, Chief Chemist, Hurley, New Mexico, for the appended chemical analysis for which about 1.5 grams of carefully selected material was furnished.

	Per cent	Insoluble deducted
Insoluble	7.70	—
Te	87.00	94.28
S	1.85	2.01
Bi	3.12	3.38
	99.67	99.67

So far as the writer has been able to determine this occurrence of native tellurium is the first to be mentioned in the state. Tetradymite, or probably more properly named, tellurobismuthite, has been reported from Hachita, New Mexico.[1]

UNUSUAL FELDSPAR CRYSTALS AT MONETA, VIRGINIA

James H. Benn,* *United States National Museum.*

The Seaboard Feldspar mine, near Moneta, Nelson County, Virginia, has produced some unusual crystals of feldspar. This occurrence is exceptionally interesting due to the frequency of crystals remarkable for their size and sharpness of form. The advisability of securing one of these for exhibition was brought to the attention of the United States National Museum by Dr. W. T. Schaller, who, while visiting the locality saw a huge crystal which had been removed from the mine. Museum authorities then communicated with the Seaboard Feldspar Company in Baltimore, who offered to present the crystal provided the Museum assumed the responsibility of transportation. Fearing damage if shipment were made by freight or express, the writer was detailed to superintend the removal of the crystal and its transportation to Washington by truck.

The workings of the Company are located about 250 miles southwest of Washington and a short distance from Moneta, Va., and consist of an open pit approximately 500 feet long, 200 feet wide, and 100 feet deep, situated on the crest of a hill. In character the formation is a pegmatite occurring in the metamorphosed rocks of the Piedmont. The mine is approached most conveniently via Bedford, Va., preferably by auto. About a mile from Moneta, the road comes to a T-shaped junction; following the left branch for some 300 or 400 yards, a road to the right is encountered, which eventually leads to the site of the workings. Piles of debris mark its location, visible to the right about a mile from the point where the last mentioned road is entered.

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[1] Short, M N., and Henderson, E. P., Tetradymite from Hachita, New Mexico: *Amer. Mineral.*, Vol. **11**, No. 11, Nov. 1926, pp. 316–317.

* Published by permission of the Secretary, Smithsonian Institution.

The large crystal of orthoclase proved fully equal to expectations, weighing approximately 800 pounds and measuring about 2 feet high and 3 feet long. It was transported safely and is now on exhibition in the hall of economic geology (Nat. Mus. No. 96,543).

A smaller and more perfect crystal, weighing 62 pounds and measuring 16 by $9\frac{1}{2}\times 6$ inches, was secured at the mine from Mr. B. O. Harris (Nat. Mus. No. 96,561). Measurement with a hand goniometer resulted in the following determinations:

$c(001)$ large
$b(010)$ large
$z(130)$ large
$m(110)$ medium
$o(\bar{1}11)$, one large, one small
$x(\bar{1}01)$ small

The crystal habit is very much elongated, parallel to the *a* axis, with *c* face one and one-half times as wide as *b*, or nearly equal in size. In general the habit of feldspar from this locality tends toward an elgonated form. One crystal reported from the mine had a six-inch base and was elongated to six feet. The superintendent of the mine described it as resembling the Washington monument. The specimen, after being held at the mine for some time, suddenly disappeared; it is thought to have been stolen.

Associated minerals found occurring with the feldspar are quartz (mostly massive), muscovite, pyrite, limonite, zoisite, thulite, and spessartite, of which the writer was permitted to collect samples. Among several of the larger feldspar crystals observed in the walls of the mine was one measuring approximately 3 feet wide and 6 feet high. All of those seen rested in place vertical to the bottom of the pit. Estimates show that more than 30,000 tons of commercial feldspar have been removed since 1925.

BOOK REVIEWS

SIMPLE DETERMINATIVE MINERALOGY, H. R. BERINGER. 239 pages. Mining Publications, Ltd., 724 Salisbury House, *London*, E. C. 2. **1931**. Price 10s.6d.

This text is a revised and enlarged edition of "Mineral Determination," a book by the same author that was published some time ago. The method employed for the classification of minerals is one based mainly on specific gravity, supplemented by brief descriptions of physical and chemical characteristics. The scheme outlined is one that has been used for over ten years at the School of Metalliferous Mining at Camborne, Cornwall.

While a number of suggestions are offered for the determination of the specific gravity of a mineral no reference is made to the use of the Jolly balance which is, in most cases, the most useful instrument for this purpose. As the tables are unusually comprehensive in the number of minerals included the text should prove of service in determinative work.

W.F.H.

PETROGRAPHY AND PETROLOGY, FRANK F. GROUT. XVIII+522 pages, 265 figures. McGraw-Hill Book Co., *New York*. **1932**. Price $5.00.

The purpose of this textbook, according to the author, is to combine a moderately advanced laboratory study of rocks with a classroom discussion of the origin of the features seen in the laboratory. It was essential that the student should be enabled to distinguish between fact and theory. Considering the wealth of theories, many of which appear to be generally accepted as fact in the field of interpretive petrology, it was no simple task to separate fact from theory. The author has been remarkably successful in his efforts to achieve these distinctions.

Twenty-eight criteria tables are distributed through the text. This feature together with the painstaking fact-theory distinctions give this textbook its maximum value to the student.

The book is divided into eight parts. Part I consists of a very brief introduction to the subject and methods; II, The petrography of igneous rocks; III, Petrology of igneous rocks; IV, Petrography of sedimentary rocks; V, Petrology of sedimentary rocks; VI, Petrography of metamorphic rocks; VII, Petrology of metamorphic rocks; VIII, Tables of rock-forming minerals and selected readings.

Practically all rocks described and illustrated represent Minnesota occurrences. The temptation must have been great to repeat the conventional type examples throughout the world. The student is fortunate in having the happy choice limited to occurrences with which the author is thoroughly familiar.

It hardly appears necessary to add that there was a great need for an up-to-date English text on the subject.

ERNEST E. FAIRBANKS

NEW MINERAL NAMES

Glaucocerinite

E. Dittler and R. Koechlin: Über Glaukokerinit, ein neues Mineral von Laurion (Glaucocerinite, a new Mineral from Laurion). *Cent. Min. Geol. und Paleont.*, Abt. A, No. 1, pp. 13–17, 1932.

Name: From the Greek words for blue and waxy.

Chemical Properties: A hydrous basic sulfate of zinc, aluminum and copper: $Zn_{13}Al_8Cu_7(SO_4)_2O_{30} \cdot 34H_2O$. Analysis: ZnO 37.95, Al_2O_3 15.40, CuO 19.26, SO_3 5.79, H_2O+5.69, H_2O- 16.31; Sum 100.40. Soluble en hydrochloric acid.

Physical and Optical Properties: Color sky blue to turquois blue, at times greenish, and gray or brownish through impurities. Soft, waxy to radial fibrous. Sp. Gr. 2.749.

Extincton parallel. $\gamma = 1.542 \pm .001$. Birefringence is high.

Occurrence: Found as a fine botryoidal coating on adamite or with gypsum in vugs in smithsonite at Laurion.

Discussion: Differs from zinkaluminite chiefly in its content of copper.

W. F. Foshag

Alkanasul

Jorge Westman: Alkanasul, un nuevo mineral aluminifero de Chile. (Alkanasul, a new aluminous mineral from Chile), *Bol. Minero. Soc. Nac. Minera.*, **47**, 433–4, 1931.

Name: From the chemical symbols of its constituents, aluminum, potassium and sodium, and the first syllable of sulfate.

Chemical Properties: A basic sulfate of aluminum, potassium and sodium: $K_2SO_4 \cdot Na_2SO_4 \cdot 2(Al_2(SO_4)_3 \cdot 6Al(OH)_3 \cdot 6H_2O$. Analysis: Al_2O_3 30.35; K_2O 5.61; Na_2O 3.70; SO_3 37.95; H_2O 16.11; Fe_2O_3 1.20; SiO_2 4.98. Insoluble in water or acids. After moderate roasting yields soluble sulfates of alumina, potassium and sodium.

Physical Properties: Color yellowish white to bluish gray. Hd. 4½. Sp. Gr. 2.90.

Found in large quantity, in compact masses or sandy conglomeratic masses, near Salamanca, Chile.

W.F.F.

Leucophosphite

Edward S. Simpson: Contributions to the Mineralogy of Western Australia. Series VII. *Jour. Roy. Soc. W. Australia*, **18**, 69–74, 1931–32.

Name: From the Greek *leukos*, white; *phosphoros*, the root of phosphate.

Chemical Properties: A hydrous phosphate of potash, iron and aluminum: $K_2(Fe, Al)_7(OH)_{11}(PO_4)_4 \cdot 6H_2O$. Analysis (after deducting 52.75% quartz, 0.48% rutile, 1.07% chromite, and 1.03% carbon, etc.): Al_2O_3 12.73; Fe_2O_3 32.82; Cr_2O_3 nil; FeO nil; MnO 0.22; MgO 0.73; CaO tr.; $(NH_4)_2O$ 0.09; Na_2O 0.13; K_2O 7.88; $H_2O +$ 12.28; P_2O_5 26.69; NiO tr.; CO_2 0.17; Carbon tr.; SiO_2 nil; TiO_2 nil; H_2O- 6.59. Total 100.33.

Soluble in strong hydrochloric acid. Insoluble in water.

PHYSICAL AND OPTICAL PROPERTIES: Color white. Under the microscope, very fine grained. Birefringent. Sp. Gr. between 2.30 and 2.65.

OCCURRENCE: Found as chalky masses intimately associated with variscite (redondite), chalcedony and opal in veins replacing serpentine. Suggested as resulting from the action of solutions of bird guano upon the serpentine.

W.F.F.

NEW DATA

Julienite

Original description: Alfred Schoep: *Natuur. Wetenschappelijk Tijdschrift*, 10 jg No. 2, pp. 58–9, **1928.**

New data: *Ibid.*, 13 jg. No. 3–5, pp. 147–149, **1931.**

CRYSTALLOGRAPHIC PROPERTIES: (On recrystallized mineral), tetragonal, habit slender prismatic $c=p_0=1.2059$. $a_0=0.8292$. Forms: (010), (490), (350), (110) (111).

PHYSICAL AND OPTICAL PROPERTIES: G. = 1.594.

Uniaxial positive. $\epsilon=1.645$. $\omega=1.556$. Feebly pleochroic. Julienite does not seem to contain chlorine nor NO_3 as previously reported.

W.F.F.